

Joint Scalable Coding and Routing for 60 GHz Real-Time Live HD Video Streaming Applications

Joongheon Kim, *Member, IEEE*, Yafei Tian, *Member, IEEE*, Stefan Mangold, *Member, IEEE*,
Andreas F. Molisch, *Fellow, IEEE*

Abstract—Will be submitted later.

Index Terms—60 GHz, Multi-Gbit/s HD Video Streaming, Wireless Video Quality Maximization, Routing

I. INTRODUCTION

Will be submitted later.

REFERENCES

- [1] P. Smulders, "Exploiting the 60 GHz Band for Local Wireless Multi-media Access: Prospects and Future Directions," *IEEE Communications Magazine*, 40(1):140-147, January 2002.
- [2] H. Singh, J. Oh, C. Kweon, X. Qin, H.-R. Shao, and C. Ngo, "A 60 GHz Wireless Network for Enabling Uncompressed Video Communication," *IEEE Communications Magazine*, (46)12:71-78, December 2008.
- [3] WirelessHD: <http://wirelesshd.org>
- [4] Wireless Gbit Alliance (WiGig): <http://wirelessgbitalliance.org>
- [5] IEEE 802.15.3c Millimeter-wave-based Alternative Physical Layer Extension; <http://www.ieee802.org/15/pub/TG3c.html>, October 2009.
- [6] IEEE 802.11ad VHT Draft Version 5.0: http://www.ieee802.org/11/Reports/tgad_update.htm
- [7] H. Su and X. Zhang, "Joint Link Scheduling and Routing for Directional-Antenna Based 60 GHz Wireless Mesh Networks," in *Proceedings of IEEE Global Communications Conference (GLOBECOM)*, Honolulu, HI, USA, December 2009.
- [8] A.F. Molisch, *Wireless Communications*, 2nd Edition, Wiley-IEEE, February 2011.
- [9] Comotech Corporation; <http://www.comotech.com/en/index.html>
- [10] Millitech; <http://www.millitech.com/>
- [11] M.-C. Hwang, J.-H. Kim, D.T. Duong, and S.-J. Ko, "Hybrid Temporal Error Concealment Methods for Block-Based Compressed Video Transmission," *IEEE Transactions on Broadcasting*, 54(2):198-197, June 2008.
- [12] L. Zhou, B. Geller, B. Zheng, A. Wei, and J. Cui, "System Scheduling for Multi-Description Video Streaming Over Wireless Multi-Hop Networks," *IEEE Transactions on Broadcasting*, 55(4):731-741, December 2009.
- [13] H. Zhai, X. Chen, and Y. Fang, "Improving Transport Layer Performance in Multihop Ad Hoc Networks by Exploiting MAC Layer Information," *IEEE Transactions on Wireless Communications*, 6(5):1692-1701, May 2007.
- [14] J. Kim, Y. Tian, A.F. Molisch, and S. Mangold, "Joint Optimization of HD Video Coding Rates and Unicast Flow Control for IEEE 802.11ad Relaying," in *Proceedings of the 22nd IEEE International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC)*, Toronto, Canada, 11 - 14 September 2011.
- Parts of this paper were presented at the 22nd IEEE International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), Toronto, Canada, 14 September 2011 (refer to [14]).
- J. Kim is with the Department of Computer Science, University of Southern California, Los Angeles, CA 90089, USA e-mail: joongheon.kim@usc.edu.
- Y. Tian is with the School of Electronics and Information Engineering, Beihang University, Beijing 100191, China e-mail: ytian@buaa.edu.cn.
- S. Mangold is with the Disney Research Zurich and the Laboratory for Software Technology, ETH Zurich, 8092 Zurich, Switzerland e-mail: stefan@disneyresearch.com.
- A.F. Molisch is with the Ming Hsieh Department of Electrical Engineering, University of Southern California, Los Angeles, CA 90089, USA e-mail: molisch@usc.edu.
- [15] C. Cordeiro, D. Akhmetov, and M. Park, "IEEE 802.11ad: Introduction and Performance Evaluation of the First Multi-Gbps WiFi Technology," in *Proceedings of the 1st ACM International Workshop on mmWave Communications: from Circuits to Networks (mmCom)*, Chicago, IL, 2010.
- [16] H.L. Cycon, V. George, G. Hege, D. Marpe, M. Palkow, T.C. Schmidt, and M. Wahlisch, "Adaptive Temporal Scalability of H.264-compliant Video Conferencing in Heterogeneous Mobile Environments," in *Proceedings of IEEE Global Communications Conference (GLOBECOM)*, Miami, FL, USA, 6 - 10 December 2010.
- [17] M.-P. Kao and T.Q. Nguyen "Rate-Distortion Optimized Bitstream Extractor for Motion Scalability in Wavelet-Based Scalable Video Coding," *IEEE Transactions on Image Processing*, 19(5):1214-1223, May 2010.
- [18] C.-Y. Tsai and H.-M. Hang "Rate-Distortion Model for Motion Prediction Efficiency in Scalable Wavelet Video Coding," in *Proceedings of the IEEE Packet Video Workshop*, Seattle, WA, USA, 11 - 12 May 2009.
- [19] J. Cao and C. Williamson, "Towards Stadium-Scale Wireless Media Streaming," *Proceedings of the 14th IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS)*, Monterey, CA, USA, 11-14 September 2006.
- [20] M.M. Akbar, M.S. Rahman, M. Kaykobad, E.G. Manning, and G.C. Shojja "Solving the Multidimensional Multiple-Choice Knapsack Problem by Constructing Convex Hulls," *Computers and Operations Research*, vol. 33, pp. 1259 - 1273, 2006.
- [21] R.K. Ahuja, T.L. Magnanti, and J.B. Orlin, *Network Flows: Theory, Algorithms, and Applications*, Prentice Hall, 1993.
- [22] S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004.
- [23] S. Leyffer, A. Sartenauer, and E. Wanufelle, "Branch-and-Refine for Mixed-Integer Nonconvex Global Optimization," *Technical Report, Mathematics and Computer Science Division, Argonne National Laboratory*, 2008; Preprint ANL/MCS-P1547-0908.
- [24] J. Munkres, "Algorithms for the Assignment and Transportation Problems," *Journal of the Society for Industrial and Applied Mathematics*, 5(1):32-38, March 1957.
- [25] M. Grant and S. Boyd, *CVX: Matlab Software for Disciplined Convex Programming*, Version 1.21, April 2011.
- [26] M.-H. Lu, P. Steenkiste, and T. Chen, "Time-Aware Opportunistic Relay for Video Streaming over WLANs," in *Proceedings of IEEE International Conference on Multimedia and Expo (ICME)*, Beijing, China, 2 - 5 July 2007.
- [27] S. Mao, X. Cheng, Y.T. Hou, H.D. Sherali, and J. Reed, "On Joint Routing and Server Selection for MD Video Streaming in Ad Hoc Networks," *IEEE Transactions on Wireless Communications*, 6(1):338-347, January 2007.
- [28] W. Wei and A. Zakhori, "Interference Aware Multipath Selection for Video Streaming in Wireless Ad Hoc Networks," *IEEE Transactions on Circuits and Systems for Video Technology*, 19(2):165-178, February 2009.
- [29] S. Murthy, P. Hegde, V. Parameswaran, B. Li, and A. Sen, "Improved Path Selection Algorithms for Multipath Video Streaming in Wireless Ad-Hoc Networks," in *Proceedings of the IEEE Military Communications Conference (MILCOM)*, Orlando, FL, USA, 29-31 October 2007.
- [30] D. Giustiniano, V. Vukadinovic, and S. Mangold, "Wireless Networking for Automated Live Video Broadcasting: System Architecture and Research Challenges," in *Proceedings of the IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, Lucca, Italy, 20 - 23 June 2011.
- [31] S. Sharma, Y. Shi, Y.T. Hou, H.D. Sherali, S. Kompella, and S.F. Midkiff, "Joint Flow Routing and Relay Node Assignment in Cooperative Multi-Hop Networks," *IEEE Journal on Selected Areas in Communications*, 30(2):254-262, February 2012.

- [32] S. Singh, R. Mudumbai, and U. Madhow, "Interference Analysis for Highly Directional 60-GHz Mesh Networks: The Case for Rethinking Medium Access Control," *IEEE/ACM Transactions on Networking*, 19(5):1513-1527, October 2011.
- [33] Los Angeles Memorial Coliseum: <http://maps.google.com>